https://dx.doi.org/10.22161/ijaers.6.6.75 ISSN: 2349-6495(P) | 2456-1908(O)

Application of the Lean Manufacturing Culture: Case Study in a Cell Phone Company of the Industrial Pole of Manaus

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Abstract— *The productive potential of the industries, the increasing need for effective industrial process management and the opportunity for general improvement of corporate performance, through the application of the concept and tools of Lean Manufacturing, were the main motivating agents of this research work. In the context of this scenario, the cellular manufacturing processes were analyzed in a manufacturing company outsourced from the Industrial Pole of Manaus that uses the literature of Lean Manufacturing as a pillar of support to confection of its functional processes. The case study was structured in three distinct parts: analysis of the original situation of the company, identifying opportunities for improvement according to the specificities of the process flow; application of the identified improvements and finally a comparative analysis between the data obtained with the improvements on the processes with respect to the wastes identified.*
Keywords— ***Lean Manufacturing, Value Stream, Productivity.***

I. INTRODUCTION

The implementation and significance of Lean Manufacturing in industry is confused with the history of the industrial revolution itself. In this process, History reveals that success is not only evidenced by the speed of production, but by the effectiveness of productive methods and the reduction of expenses.

With globalization underway, the global market has become violently competitive, requiring cost reduction and better levels of productivity. Equity: Survival has become the big challenge organizations, which, coupled with competitiveness and technological advancement on several fronts, has emerged new organizational techniques, which seek to keep organizations in a floating state, developing administrative systems more efficiently agile and strong enough to the standards established by the mutant need of society, thus avoiding a series of wastes, including time.

Even if you started in the automotive industry, the philosophy of Lean Manufacturing is used in a variety of activities, from raw materials to distribution services and others.

In outsourced assembly companies, the uncontrolled and arithmic production means loss of inputs and time, and with the increasing demand for production, the need for faster and more efficient methods of production arises, and, in order to deal with more efficient and fast methods of producing on a large scale, even though it is considered the most effective way in terms of sustainability and economic viability, it is a process that faces many challenges, such as the difficulty in the process planning process, productive organization and the offer of quality products, once that the acceleration of the process should not occur to the detriment of the loss of quality in production.

In this context, the present work aims to verify if the tools of Lean Manufacturing can contribute positively to the assembly process of cellular devices, using numerical data regarding the production of units per hour (UPH) and the collection of information on the main factors negatives that contribute to low productivity, thus enabling the development of effective solutions that can mitigate the negative factors of production, using information such as: production time per unit, provision of inputs in the process line, quantity of defective products and final products assembled per hour of production.

II. THEORETICAL FOUNDATION

As long as technological evolution does not mitigate the need for human intervention in production processes, companies that have the assembly process, whether

https://dx.doi.org/10.22161/ijaers.6.6.75 ISSN: 2349-6495(P) | 2456-1908(O)

outsourced or not, will have challenges of agility and quality in industrial production, whether linked to the layout of the production line , agility in the exchange of information between the line and the warehouse, where the speed of production and the quantity of pieces produced per hour is a reflection of the quality in the process flow, which potentiates the added value of the final product.

Outsourced assembly companies have a system where distinct brand products are manufactured in differentiated lines, which are operated by teams unique to that process. The interval between receipt of inputs, their layout in the available layout on the production line and the delivery of the final product generates a lead time, which, depending on the size, does not add value to the product and can generate losses to the company.

2.1 Lean Manufacturing

The Lean Production System is a set of actions that aims to increase the capacity to respond to changes and mitigate waste in the productive flow, creating a transformative management organization.

In his work [1], he postulates that this system has as principles: keeping the right items in the right places, right mind and the right quantity; create and nurture effective relationships within the Value Chain; working towards Continuous Improvement in search of quality in the first unit delivered.

Regarding the identification of waste, the key point is to reach a level where the production capacity is equal to the one requested by the final customer.

This means that in the companies there are human, material, technological process flows to produce exact quantity of the service or product that was requested, all with timely delivery of the final product [2].

When this balance between capacity and load does not occur, the synthesis of these occurrences is an impediment to the company, that is, it generates waste. Taiichi Ohno (1912-1997), Toyota executive and great critic of procedural waste - identified the seven types of production waste:

2.1.1 Excess production waste:

Producing the unnecessary, taking time to prepare the necessary machinery, as well as the distances to be covered with the inputs, and the lack of coordination between different procedural sectors, inevitably leads to problems and constraints in the production process.

2.1.2 Waiting waste:

According to the Lean philosophy [3], the movement of machines is not mandatory at all times, but human productivity can not wait. The accumulation of inputs caused by the lack of material flow management and the flow of information form queues that tend to overload the use of equipment. In this sense, the Lean reaffirms the management of this flow of materials with the objective of maintaining and enhancing the flow of human production.

2.1.3 Transport and handling waste:

As indispensable activities for the production process, the flow of people and materials takes time, since the procedural limitations of production require a displacement perpendicular to the dimensions of the facilities, materials and stages of production. To reduce this movement to the maximum, either with procedural or physical changes in the installations is one of the points defended by the Lean philosophy [4].

2.1.4 Waste of the process itself:

According to [5], the production process has steps that do not always add value to the final product. How, where and why to produce are important questions at the moment of procedural management. The Lean philosophy puts in question any process that can add cost and not values to production.

2.1.5 Unnecessary waste of work:

In his work [5] he states that when a movement / process is very fast, slow or obsolete, there is no economy or a consistent approach to the processes, so if a company decides to automate such processes without the knowledge of the real needs of production, there is the risk of automating waste.

2.1.6 Waste of defective products:

Defects imply directly the waste of materials, human production flow, use of equipment besides the unnecessary storage of these poorly used inputs, problems directly linked to quality. An innovative approach to the production process that minimizes the occurrence of defects makes it possible to remanue inspection processes [1].

2.1.7 Waste storage

In its article [6] it points out "Towards Lean Product Lifecycle Management: the Framework for New Product Development", that the use of stocks in the traditional production aims to avoid productive arithmia, however this system hides quality problems by generating productive islands, the process flow, increases the occurrence of setup problems, besides causing an unnecessary occupation of the physical space that could be better used in the productive process, since there is bureaucratic and human displacement due to its existence.

2.2. Lean Manufacturing as Productive Philosophy

The concept of Lean Manufacturing is based on the naming of waste and elements that do not add value in order to reduce costs, producing defect-free goods in the shortest possible time using the least amount of equipment and labor, aiming at customer satisfaction and productivity. making it more competitive [7]. In general, the Lean system is defined as the western reading of the Japanese production model, especially the Toyota Production System (TPS).

The book "The Machine That Changed the World" by Womack (1990) popularized the Lean definition, which, in short, sought to explain the Lean system with the idea of using half human workflow, manufacturing space, investment in tools and in time in engineering, with the goal of producing a new product. As a philosophy, Lean is a specification mode that aims at enabling actions that add value while reducing costs, performing these activities uninterruptedly when they are requested and performing them every time more efficient.

In his work [8] the management literature suggests that contextual factors may present strong forces within organizations that inhibit implementations that seem technically rational. [9] addresses the benefits of lean manufacturing deployment. [10] It addresses how paradigms of lean thinking and agile manufacturing have been developed, which has been a tendency to visualize them in a progression and in isolation.

Womack analyzed the many faces of implementation and development of improvements and with the influence of the Toyota production system, identified the essential causes of these implementations, which became known as the five principles of the Lean philosophy, namely: specification of value, identification of value chain and value stream, leaving the aggregate value to the end customer, since the central objective of this philosophy is the continuous search for perfection.

III. TOOLS AND METHODS

The company targeted for the installation of the project is located in the industrial pole of Manaus of the electronics industry. In order to preserve its identity and confidential data, the present work will be directed to it only as a company.

Born in the wave of outsourcing in the 1980s, she specialized in electronic components, manufacturing computers, telephones and medical equipment, as well as being responsible for the packaging and delivery of the products.

The company operates from Monday to Saturday, in three shifts of eight hours each, in addition to the business hours (financial and administrative sector) that runs from Monday to Friday. The focus of production at the Manaus Industrial Complex is the cell phone and charger. The improvement will be applied in the cell phone line.

The first stage of assembly of the products begins in the main warehouse, where the pieces that are common to all the apparatuses like, for example, plates and structures of cellular phones used in any equipment are accumulated. From there, the products move on to the second phase.

Each brand then wins its production cell (independent units) and an exclusive team of assemblers, consisting on average of 75 people. With the flow of demand and the high complexity in materials management, the company presented a series of problems related to process management and mode of production, such as:

• Unbalanced and unbalanced production, with excessive idle time and focused operational wear.

• Loss of material from the ratio of raw material quality and asynchrony between demand and production in terms of quantity and time.

• Stock problems (warehouse): The company's warehouse had no defined pattern in relation to allocation, model identification or organization. In the case of a company that manufactures products of different brands in a product family, the differences between the models are minimal, differences that do not change its manufacturing process, but compromise its operation.

In order to understand the company's needs efficiently, quality management tools were used, including Value Stream Mapping (VSM), Ishikawa chart, Pareto chart, followed by the 5S implementation.

3.1 VSM: Value Stream Mapping

Value Stream Mapping (VSM) is a mechanism that can visually demonstrate the stages of material and information flows, while the product follows the flow of value, a helper in the perception of what value adds, from the supplier to the supplier. to the consumer. Thus, the mapping of the current state, the mapping of the future state and the mapping of what is objectified, if necessary, is developed.

This process consists in the identification of specific activities that happen during the flow of value, where value flow is the asynthesis of all the activities that happen from the request made by the customer to the delivery to the final consumer.

This is a process of understanding the production and illustration of a process map that will become the basis for Lean system deployment. In other words, represented in Figure 1, the VSM is a visual representation of the flow processes of the material and actual information synthesized into a set of key questions and with the development of a map of the desired future state of how the production should proceed.

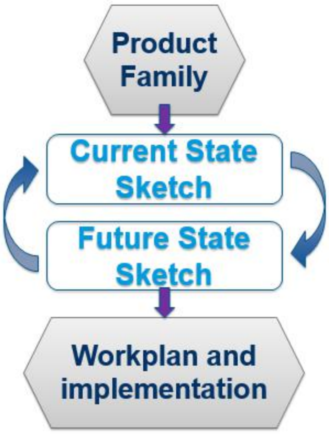

Fig. 1: Basic Mapping of Value Flow. Source: Adapted by the author

3.2 Ishikawa

The Ishikawa Diagram is a tool that enhances the graphic quality used to manage the various processes, allowing the hierarchical structuring of the motivations of a given problem and was developed with the purpose of providing a graphic view of the various causes that affect the procedural flow, by classification and relation of causes.

Besides that, it also allows the structuring of systems that need a response in a graphical and synthetic way, thus providing a detailed and holistic view on the subject studied.

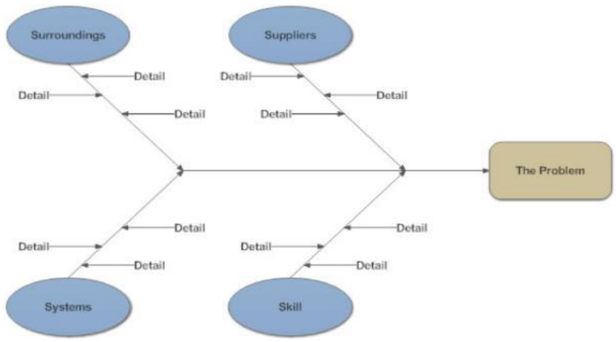

Fig. 2: Ishikawa Diagram

As can be observed in Figure 2, it is structurally composed of: head, which corresponds to the problem to be studied; scales, which correspond to the factors influencing the problem, including the subcauses, consequences and the steps to be taken for resolution. Its construction takes into account factors such as: the problem to be analyzed, possible causes for occurrence, structuring them to the left of the central problem.

3.3 Pareto Diagram

Pareto Analysis distributes a large problem in small proportions easier to solve, allowing projects to be prioritized and more concrete and tangible goals set.

The Pareto Diagram divides the problems into two classes: Few Vital and Many Trivia. So, it means to say that a problem has several causes, but only a few have a great impact or great loss.

It can be observed in Figure 3, the Pareto Diagram consists of vertical bars that represent the causes of a given problem, ordered in descending order of incidence, in addition to a line of cumulative percentages that show the causes of greater impact.

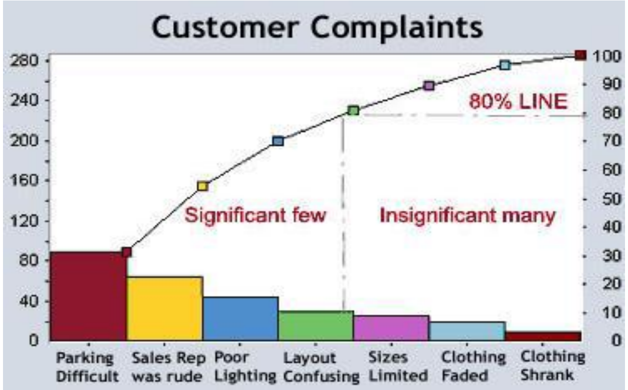

Fig. 3: Pareto Chart Scheme. Source: (ROUSE, M. 2011)

3.4 Tool 5'S

5's is a widely used tool in the implementation of the Lean concept and its main objectives are to improve the quality of products, work environment and customer service, the quality of life of employees and maximize the use of available resources, reducing waste and taking advantage of to maximize physical space, in addition to reducing and preventing accidents, improving human relations and increasing employee self-esteem.

The 5S acronym was originated from Japanese words beginning with the letter S: Seiri (Sense of Use), Seiton (Organization Sense), Seiso (Sense of Cleanliness), Seiketsu (Sense of Health and Hygiene) and Shitsuke (Sense of Discipline).

Among them, the concepts of Organization and Cleanliness are fundamental to the process of implementation of the concept of Lean production, because only in this way will it be possible to clear clear problems, satisfactory control of waste products, besides the gain of productive reliability, which comes to produce control and gain the quality of production by increasing the quality of the processes and the working conditions in which the employees will be inserted.

https://dx.doi.org/10.22161/ijaers.6.6.75 ISSN: 2349-6495(P) | 2456-1908(O)

IV. LEAN MANUFACTURING IMPLEMENTATION

The implementation of the project was initiated through a technical analysis in the cellular line with the purpose of knowing the process and collecting the necessary data for conclusion of the study. With this purpose were used as sources of information: the records, Kaizen event and direct observation in the production line where the cell line needed to produce 340 cell phone per hour to meet the customer and the current hour production was in 289 cell. .

After a first low productivity analysis, the company team was assembled to outline the nature and dimensions of the causes of the problem, in this case the low productivity in the cell phone line.

A Kaizen event was held to better understand the production flow and identify opportunities for improvement, minimizing waste and gaining productivity. A questionnaire was also distributed to operators where they could expose their greatest difficulties.

On the second day, based on information obtained locally, the graphical versions of the Value Stream, Ishikawa Diagram were constructed, where the causes of the production problem were instated and the Pareto Diagram was constructed, where all negative points and difficulties encountered by presenting the current state.

4.1 Analysis of the data

Analyzes of the implementation data were performed, which will be presented below, in the topics VSM analysis, application of Ishikawa, use of data in Pareto diagram, implementation planning and execution.

4.1.1 VSM Analysis

Based on the technical analysis a map was developed of the value stream of the cell line and the following information was verified: There are eight workstations in the process called the bottom phase (where all the components of the bottom of the circuit board are assembled printed) and according to the flow of this process it was identified that in the first station there was excess of stopped material to enter the line.

In the process called top phase (where all the components of the printed circuit board are assembled, with 10 workstations), it was identified in the first position that there was an excess of material stopped, and that in the last station the excess of material was much larger, causing the whole line to stop.

In this position the machine responsible for cutting the boards (Router machine), was intermittent stop with several false failures, the operator was busy with activities, there was no standardization of work, the layout was not adequate, there was no maintenance plan for the equipment. In Figure 4, the construction of the VSM is presented.

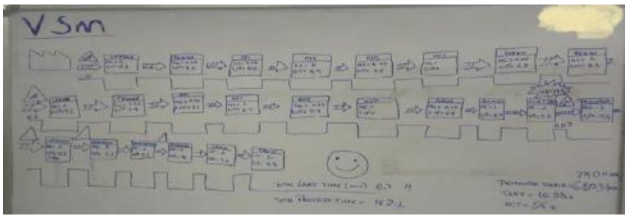

Fig. 4: Development of VSM

In the next process, where the assembly was done, there was a lot of excess material stopped in the process.

4.1.2 Application of Ishikawa

After analyzing the value flow, a Pareto diagram was constructed with the causes of low productivity in the cell line. Among the causes identified were:

• High temperature: The production area was in an environment that presented excess heat causing fatigue to employees, stopping machines for false failures.

• Operator without training: There was no standard operation or standardization documents were not in line with the reality of the process, causing meontage delay, assembly defect or even parts scrap.

• Incorrect Flow: There was no clarity in the flow of this process.

• Failures in the AOI: SMD component inspection machine responsible for identifying if there was a wrong assembly, for example, if the resistor was not mounted in the capacitor position, if the components were correctly assembled without displacements, it had excessive faults.

• Test Failure: Responsible testing to check the circuitry of the phone's circuit board was exhibiting false failures from the external heat of the environment.

• Router: Router machine responsible for separating the cell phone boards from the matrix through cuts according to program that model asked was presented exose from false failures, machine was breaking frequently.

• Output of botton pieces: Production of the bottom phase was not attending the top phase.

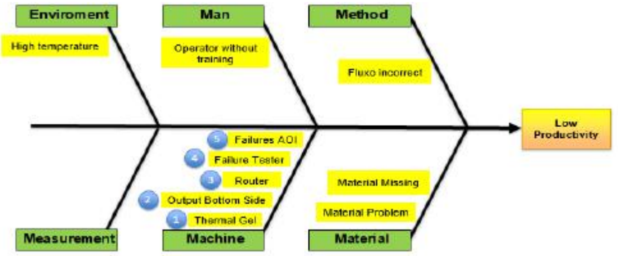

Fig. 5: Ishikawa diagram with visualization of causes

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• Thermal gel: Process of applying the thermal gel on the cell plates was causing excess defects, machine was intermittent failure.

• Loss of Material: Material misallocated, were not obeying the fifo (first that enters is the first one that leaves).

• Material Problems: Material delivered by the external supplier was presented with many defects.

4.1.3 Using the Data in a Pareto Diagram

After analyzing the Ishikawa plot, we extracted the information from the Pareto process, where it was possible to identify the main villains that were directly impacting the low productivity of the cell line, confining past insfomings of the responsible areas such as quality, productivity, pcp.

As shown in Figure 6, each problem was analyzed and each team member was responsible for each action to be taken to solve each identified problem.

Fig. 6: Pareto diagram with data obtained

The main villains shown in the pareto were: Frequent breaking machine, where the application method was not meeting the quality plan; layout was not clear; process of the bottom production phase was not meeting the top production process due to a series of defects in the process and machine stops; router machine breaking frequently, there was no claresa in the operation execution process, excessive false faults due warm environment; testing machine were with excessive false failures due to warm environment, there was clarity in the process of the operating method of work.

In addition, the component inspection machine on the printed circuit board AOI was exhibiting false failures, many machine breakdowns; NXT machine responsible in the icersion of compontes in printed circuit board was with posing false faults, stopping for lack of compentes, warm environment; material from the external customer.

4.2 Implementation Planning

The cell line was with low productivity, as can be seen in Figure 7, which was marking the production of 2268 cell phones per day, while the amount requested in the customer order would be 2720 cell phones per day.

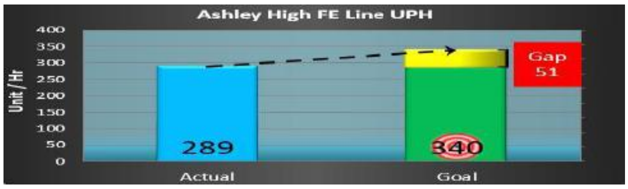

Fig. 7: Definition of target to be achieved

To achieve this goal in the three shifts, each shift would have to produce 340 cell phones per hour. With the presentation of the procedural problems in the analysis phase, some possible changes in the cellular line were visualized without the need for large investments, reaching the goal of the production value requested by the customer.

4.2 Execution

It was found that the test coverage device Jig did not close properly because the pin was worn causing intermittent failures causing downtime and productivity delays. Figure 8, After analysis in the process with the team involved, a pin with a larger thickness was used together with the moonshine section to lock the top of the cellular apparatus, after this adaptation the freeness problems were eliminated.

Fig. 8: Pin Lock

Piece of kapton tape from the components below, causing the test to fail. This problem was occurring frequently, and whenever the tests began to fail, the technician was required to stop the process for repairing the tests once the tests were filled with tape attached to the test needles.

During the analysis, it was defined that the employee who received the plates of the post-refueling process made the removal of the tape that was fixed between the

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pallet and the plate of the cellular and defined maintenance plan of the palles through a control of maintenance shown in Figure 9. After the actions taken the intermittent problem that there was in the process was solved.

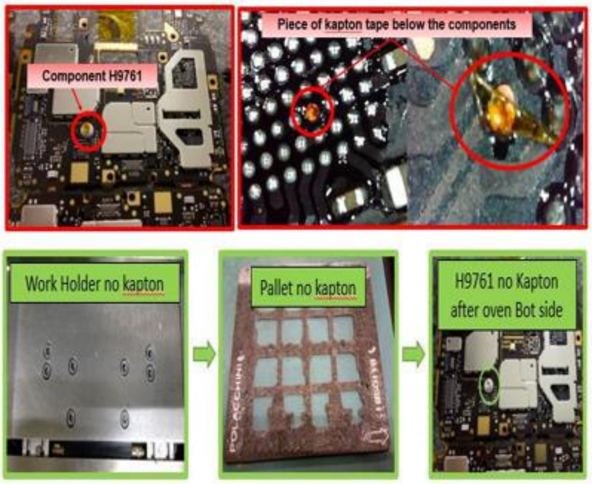

Fig. 9: Maintenance of the yards

Disorganized visual inspection station. The activities carried out by the collaborator were not clear, on the bench there were many materials that were not being used, there was excess of movement in the accomplishment of the activities. A 5S was defined in the area of visual inspection so that after the end, the activities carried out by the collaborator of this post were organized, improving the egonomic part and gain in the execution time of their activities, shown in Figure 10.

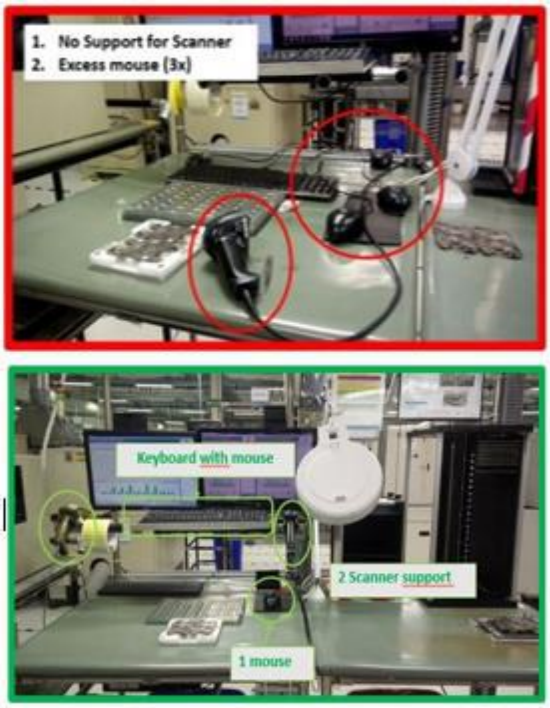

Fig. 10: Organization of 5s

There was no visual management to inform operators of quality and productivity indicators, so the process developers did not know how their production goals were and how quality of hour-and-hour production was.

Once this need was identified, a visual management framework was developed and each strategic point of the mobile phone line was installed so that all of that process had the goal information, hours produced and the number of defects in the line. This idea of implantation of visual management, Figure 11, made the actions to be taken in the process were more agile and effective.

Fig. 11: Visual management information frame

In the process of applying plate likes there was no weighing control, this lack of weighing control was causing defects. These defects were identified in the tests where the plates were failing because the amount of material applied on the plate was not as defined by the quality. In order to solve this problem, we used a feature that we already had in mind, but the only idea was to introduce this line, which was a device, shown in Figure 12, to warn the employee to check weighing after 12 plate pallets made in your process.

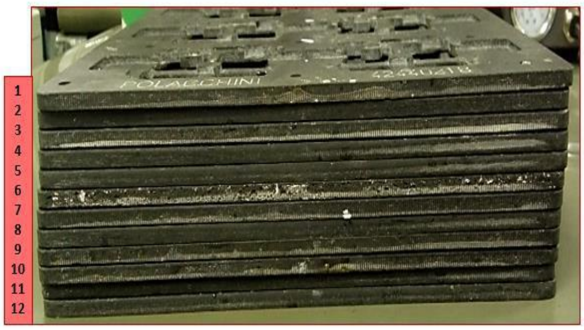

Fig. 12: Plate pallets

In the reflow phase in the welding furnace, which consisted in the solderability of the SMD components of the board, we were having solder defects. Adjustments were made in the weld profile and enabled the nitrogen a

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feature that the reflow oven machine has. After the improvement actions in the reflow oven process, the welding failure in the plate components in the process is over.

In the post-furnace reheat phase, the plates were coming off with an excessive temperature causing false failures in the tests. After analysis with the team, it was adapted blowers / fans in magazines where the plates passed out of the furnace straight to the magazzine responsible for cooling the plates. This idea not only solved the false failures in the tests but also improved the activity of the operator receiving these plates from the reflow oven.

In the test benches there was no control of pattern of faulted plaques. This form of work was generating bench reprocessing because there was no set location for the tested boards and boards that were missing to test. The solution to this problem was to make a new layout, shown in figure 13, where the dots were identified to avoid re-testing.

Fig. 13: New Layout

In the process of separation of the cellular plates carried out by the router machine through cuts, there were two operators where each one carried out its activities. After the re-layout improvements, shown in Figure 14, adapted in the process, it was possible to eliminate one station from that machine and relocate the operator to another activity in the factory, thus reducing a quand we had in the three shifts in the cell line of 78 employees for 75 employees. This change in productivity did not affect productivity.

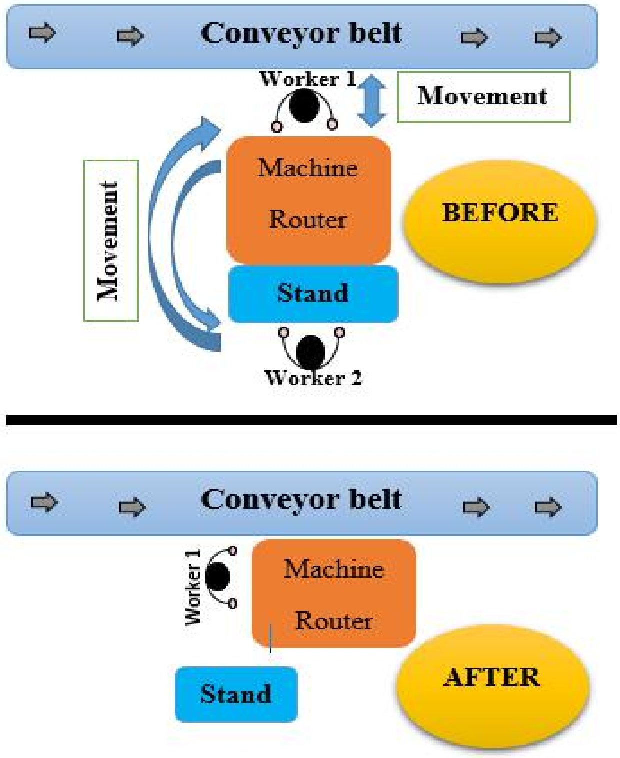

Fig. 14: before and after the implementation of the new layout

All stages of lean manufacturing implementation were performed.

V. RESULTS AND DISCUSSIONS

After all the actions performed and follow-up in the process of the implementation week, the application of the Lean and with the use of the help tools was obtained a significant improvement in the productivity of the company, as shown in figure 14. During the first two days, improvements were implemented gradually, it was verified that the productivity was still below the expected, already after the following days, the results of the implementation were achieved with good results.

CTQs		Measurement		Start	Target	Target Imp'mt	Kaizen Week					Kaizen Week					Actual	
		UoM	Criteria				Day 1	Day 2	Day 3	Day 4	Day 5	Day 1	Day 2	Day 3	Day 4	Day 5	Result	Imp'mt
P	1- PCBA Productiy UPH	unit	Hr	289	340	18	243	303	346	353	344						344	108
D	2- FPY	%	Day	96	98	2	98.45	98.2	98.31	98.2	97.98						97.98	99
P	3- DL	person	Person	78	75	4	75	75	75	75	75						75	100

Fig. 15: Productivity results during deployment week

However, from the implementations and structural modifications, in this case (in particular) the layout of the production line, were definitive factors for the agility of response to occurrences within the sector, shown in figure 16.

LOSS	PROBLEMS	SOLUTION	GAIN
Overproduction	Asynchrony between demand and productivity	Analysis of component production and implementation of relayout	25% increase in assembly line productivity.
Wait	Lack of stock standardization (quality)	5s Tool Application	Savings of up to 5 minutes in raw material demand
	Machine Unavailability	Biweekly and weekly preventive maintenance plan	
Transport	Ineffective layout in assembly	Restructuring the layout	Average Production of 1 cell phone every 10 seconds
Process	Assembly process divided into two steps without need	Restructure activity with the router	Decrease in operational staff per shift.
Products Defective	Processing of defective products	Elaboration of discards guide	Creation of flow chart as a decision tool

Fig. 16: Analysis and proposal of solutions

Thus, it was possible to verify the productivity increase from 289 units / hour to 340 units / hour, with one operator per shift reduction, and (FPY - first pass yild) yilde increase to 2%.

ACKNOWLEDGEMENTS

To the engineering coordination of the FAMETRO university center, and the teachers M.Sc. Marden Eufrasio dos Santos and Dr. David Barbosa de Alencar, for the support in the development of this work.

To the Institute of Technology and Education Galileo of Amazon (ITEGAM), Brazil.

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